

THE RESEARCH ON DETERMINATION OF THE OPTIMUM PARAMETERS FOR LUBRICATION FOR SKD11 STEEL SURFACE GRINDING

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ABSTRACT

This article presents empirical research for determining the optimal value of the flow and concentration of lubricant when processing SKD11 steel on the surface grinder. In this research, the central composite design is used with a matrix of 13 experimental points when changing the input parameters of the lubrication parameters. The experiment is carried out with 36A60LV grinding wheel and TECTYL COOL 290MC lubricant. Based on the experimental results, the influence degree of the concentration and the flow of lubricant on surface roughness has been analyzed. The results show that the parameters of the flow and concentration of lubricant as well as the interaction between such two parameters significantly affect the surface roughness of the workpiece, in which the influence degree of the solution concentration on the surface roughness is greater than that of the solution flow. Later, this research also shows the optimal values of the two above parameters.

KEYWORDS: Surface Grinding, SKD11 Steel & Lubrication Parameters

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1. INTRODUCTION

In mechanical processing, grinding is often chosen as the final processing method for important surfaces, in which high surface precision and lustre are requested. Surface quality when grinding is assessed through many parameters, in which surface roughness is one of the important parameters. This parameter has a great influence on the use of the surface of the machine parts. Surface roughness is often chosen as a criterion for evaluation of the grinding process. There are many factors that affect surface roughness when grinding, in which the parameters of lubrication technology have a great influence on surface roughness (Stephen Malkin and Changsheng Guo 2008). There are three popular cooling-lubrication methods used in grinding: Cooling Flood Lubrication - CFL, Minimum Quantity Lubrication - MQL and Dry Grinding-DG. These methods have been studied and applied in grinding. However, in practical production, the method of cooling flood lubrication is still used more commonly thanks to the effects of fast heat transfer out of the cutting zone, lubrication of cutting zone, reduction of friction between surface of workpiece and grinding wheel (Le Xuan Hung et al. 2018). The determination of the value of the parameters of lubrication technology for the workpiece surface with minor surface roughness will contribute to improving the economic and technical efficiency of the grinding process. In the literature, there have been many type of research on lubrication technology when grinding, the main goal of such researches is to determine the value of lubrication parameters, or new methods of lubricant, or researches for a new solution, etc in order to process the workpiece surface with minor surface roughness.

The influence of pneumatic pressure when compressed air is blown into the grinding zone during machining SCM4 steel and SCM21 steel with CBN grinding wheel had studied (H.Z. Choi et al. 2011). The influence of cold air flow pressure mixed with vegetable oil on surface roughness when grinding tool steel had studied (K. Q. Xiao and L.C. Zhang 2006). Determining the optimal value of concentration, flow, and pressure of lubricant when grinding 9CrSi steel with Oemeta Unimet AS 192 oil had done (Hoang Xuan Tuet al.2018; Hoang Xuan Tu et al. 2019). The influence of workpiece velocity on surface roughness when grinding AISI1050 steel with Al_2O_3 grinding wheel in two cases: dry grinding and grinding with emulsion 5% had studied (M. Kiyak et al 2003). The grinding process with lubricants: cooling air, emulsion 4%, and compressed air combined with mist water tested (HZChoi et al. 2001). Researching on grinding SUJ2 bearing steel with Al_2O_3 grinding wheel and CBN grinding wheel on the surface of workpiece had conducted (Do Duc Trung 2010). In this research, the method of cooling flood lubrication with a flow of 25 litre/min for four types of lubrication solutions including Emulsion, Machinery coolant, Tectyl cool 1240, Tectyl cool 1290 is used. The influence of lubricant concentration on surface roughness when grinding stainless steel 3X13 with black silicon carbide grinding wheel has experimentally studied (Ngo Cuong and Nguyen Dinh Man 2009). Experimentally studied on grinding the AISI 304 stainless steel on the surface grinder with two cooling-lubrication methods: using soluble oil and using liquefied nitrogen gas (Nabil Ben et al. 2006). The influence of type of lubricant on surface roughness when grinding 9XC steel with three types of cooling lubricants: Caltex Aquatex 3180 oil, AVANTIN 361I oil and JP Way oil had studied (Nguyen Thi Thu 2015). Many studies on nozzle-formed design, position of cooling lubricant nozzle during the grinding process (Webster and Cui C [13] 1995). Grinding the GCr15 with CBN grinding wheel in two cases of dry grinding and wet grinding had tested (Stephenson 2003) and so on.

SKD11 steel is a type of material widely used in mechanical engineering for making dies, cutting tool, etc thanks to outstanding advantages such as high hardness, high abrasion resistance, low tempering stress, etc. This is a type of steel commonly used in grinding technology. However, until now, no research has shown the optimal value of lubrication parameters when processing this material on surface grinder. This issue will be studied in this article to process the surface of the machine parts with minor surface roughness.

2. GRINDING EXPERIMENT

2.1. Experimental Component

The component material was SKD11 steel under thermal treatment at the hardness of 58÷62HRC, 80x40x10mm size. The chemical composition of major elements of SKD11 steel after thermal treatment is presented in Table 1.

Table 1: Chemical Composition of SKD11 Steel

Element	C	Mn	Si	Cr	Va	Mo	Ni
%	1,5	0,3	0,25	11,5	0,25	0,3	0,35

2.2. Machinetool and Grinding Wheel

The surface grinder and grinding wheel used in this study have the symbols APSG-820/2A (Figure 1) and 36A60LV, respectively; the size of the outer diameter x height and inner diameter of the wheel are 180x13x31.75.



Figure 1: Experimental Machine-Tool

2.3. Measuring Equipment

Surface roughness is measured by Tester SJ-201 (Mitutoyo - Japan), shown in Figure 2. Each sample is measured 3 times and the roughness value at each test is the average value of 3 consecutive measurements.



Figure 2: SJ-201 Roughness Tester

2.4. Coolant

The coolant used in this research is TECTYL COOL 290MC (Korean). This type of oil is commonly used in cutting processing in general and processing by grinding method in particular.

2.5. Design of Experiment

The Central Matrix Design (CCD) matrix is used in this research. This is the most common matrix when studying on the optimization in mechanical engineering (Raymond H. Myers et al. 2009). The number of experiments of the matrix includes: $2^k = 4$ in original experiment, in which $k = 2$ identified as the number of the experimental variable; $2k = 4$ number of axial experiments at coding levels α and $-\alpha$, where $\alpha = \sqrt[4]{2^k} = \sqrt[4]{4} = 1.41$; the number of central points is 5 (Raymond H. Myers et al. 2009). Accordingly, the experimental matrix in this research consists of 13 experiments (Table 2). The values of the experimental variables corresponding to the coding values are presented in Table 3.

Table 2: Experimental Design Matrix

No	Flow, F	Concentration, C
1	-1	-1
2	1	-1
3	-1	1
4	1	1
5	-1.41	0
6	1.41	0
7	0	-1.41
8	0	1.41
9	0	0
10	0	0
11	0	0
12	0	0
13	0	0

Table 3: Design Factors and their Levels

Parameter	Symbol	Unit	Value at Levels				
			-1.41	-1	0	1	1.41
Flow	F	Litre/ min	1.52	1.8	2.5	3.2	3.48
Concentration	C	%	2.59	3	4	5	5.41

2.6. Experimental and Analytical Results

A grinding test is carried out according to the sequence of experimental points in Table 2 with the coding value of the parameters as shown in Table 3. In addition, for each experimental point, the fixed cutting parameters include: cutting speed of 26 m/s, depth of cut 0.015 mm, velocity of workpiece at 12 m/min; crossing traverse at 6mm/stroke.

Surface roughness when grinding is presented in Table 4. After using Minitab 16 software to analyze test results, we get analytical results as shown in Table 5, Table 6 and Figure 3, Figure 4.

Table 4: Experimental Results

No	Coding Value		Actual Value		Ra (μm)
	F	C	F (litre/min)	C (%)	
1	-1	-1	1.8	3	0.598
2	1	-1	3.2	3	0.59
3	-1	1	1.8	5	0.578
4	1	1	3.2	5	0.476
5	-1.41	0	1.52	4	0.593
6	1.41	0	3.48	4	0.527
7	0	-1.41	2.5	2.59	0.618
8	0	1.41	2.5	5.41	0.518
9	0	0	2.5	4	0.428
10	0	0	2.5	4	0.424
11	0	0	2.5	4	0.414
12	0	0	2.5	4	0.453
13	0	0	2.5	4	0.407

Table 5: Results of Variance Analysis

Analysis of Variance for Ra						
Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	5	0.074704	0.074704	0.014941	79.40	0.000
Linear	2	0.014651	0.014651	0.007325	38.93	0.000
F	1	0.005170	0.005170	0.005170	27.47	0.001
C	1	0.009481	0.009481	0.009481	50.39	0.000
Square	2	0.057844	0.057844	0.028922	153.70	0.000
F*F	1	0.023336	0.030694	0.030694	163.12	0.000
C*C	1	0.034508	0.034508	0.034508	183.39	0.000
Interaction	1	0.002209	0.002209	0.002209	11.74	0.011
F*C	1	0.002209	0.002209	0.002209	11.74	0.011
Residual Error	7	0.001317	0.001317	0.000188		
Lack-of-Fit	3	0.000078	0.000078	0.000026	0.08	0.965
Pure Error	4	0.001239	0.001239	0.000310		
Total	12	0.076021				

Table 6: Regression Model Information

Response Surface Regression: Ra versus F, C					
The analysis was done using coded units.					
Estimated Regression Coefficients for Ra					
Term	Coef	SE Coef	T	P	
Constant	0.42521	0.006135	69.313	0.000	
F	-0.03590	0.006849	-5.241	0.001	
C	-0.04861	0.006849	-7.098	0.000	
F*F	0.13262	0.010384	12.772	0.000	
C*C	0.14062	0.010384	13.542	0.000	
F*C	-0.04672	0.013636	-3.426	0.011	
S = 0.0137176 PRESS = 0.00249317					
R-Sq = 98.27% R-Sq(pred) = 96.72% R-Sq(adj) = 97.03%					

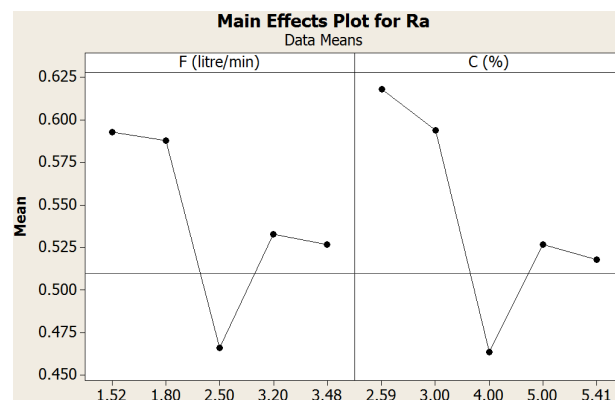


Figure 3: Graph on Influence of Parameters F and Con Ra

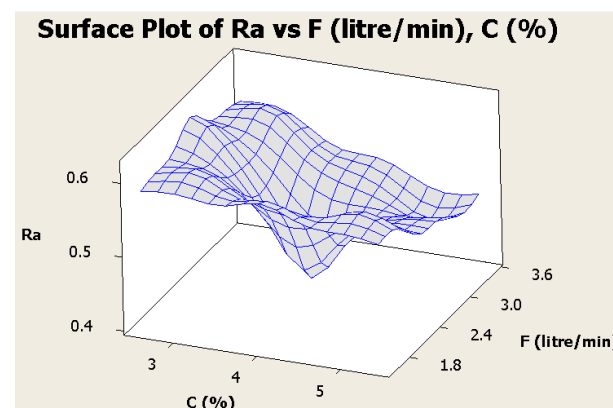


Figure 4: Graph on Interactive Influence of F and C on Ra

Based on Table 6, we determine the regression equation that presents the relationship between surface roughness and the flow and concentration of the lubricant, as shown in formula (1), with the determination coefficient of 98.27%. This equation is the basis for selecting the flow and concentration of lubricants for each specific requirement of the value of surface roughness.

$$R_a = 0.42521 - 0.0359C - 0.04861F + 0.13262C^2 + 0.14062F^2 - 0.04672CF \quad (1)$$

Based on formula 1, we solve the problem of optimizing the objective function of surface roughness to determine the optimal value of concentration and flow of lubricant. In the encoded form of the input parameters, the optimal problem is written as in expression (2).

$$\begin{cases} R_a = f(C, F) \rightarrow \min \\ -1.41 \leq C, F \leq 1.41 \\ R_a > 0 \end{cases} \quad (2)$$

Optimal value in encoded form, numerical form of flow and lubricant concentration; the surface roughness value of the workpiece are shown in Table 7.

Table 7: The Optimal Value of the Parameters

Decoded Value		Actual Value		$R_a(\mu m)$
F	C	$F(litre/min)$	$C(\%)$	
0.17	0.20	2.62	4.20	0.41

Table 5, Table 6, Table 7, Figure 3 and Figure 4 show that,

The parameters of the flow and concentration of lubricant as well as the interaction between them have a significant influence on surface roughness, in which the influence of solution concentration is greater effect than that of the flow.

The influence of flow and lubricant concentration on surface roughness is quite complicated. When the flow of the solution is increased to about 2.5 liters/min and the solution concentration is increased to about 4%, the surface roughness tends to decrease. However, if the values of these two parameters continue increasing, the surface roughness tends to increase.

The optimal values of the flow and concentration of cooling lubricant are 2.62 (liter/min) and 4.2 (%), respectively, when the processed surface roughness reaches 0.41 (μm).

3. CONCLUSIONS

Based on the results in this research, when surface grinding of SKD11 steel with 36A60LV grinding wheel, TECTYL COOL 290MC lubricant, some conclusions are given as follows.

When increasing the flow and concentration of the lubricant, surface roughness sometimes increases and sometimes decreases. When the flow of cooling lubricant is increased to about 2.5 (liter/min) and solution concentration is increased to about 4%, the surface roughness tends to decrease. However, if the values of such two parameters continue increasing, the surface roughness tends to increase.

In fine grinding conditions, if the values of the flow and concentration of lubricant are 2.62 (liter/min) and 4.2 (%)

respectively, the surface roughness will reach the smallest value at 0.41 (μm).

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REFERENCES

1. **Stephen Malkin, Changsheng Guo** (2008) *Grinding technology - Theory and Applications of Machining with Abrasives*, Industrial Press (the second edition).
2. **Le Xuan Hung, Vu Ngoc Pi, Luu Anh Tung, Vu Hong Khiem** (2018) *A Study on Coolant Parameters in Internal Grinding of 9CrSi Harden Steel*, Science and technology project at University level, Thai Nguyen University (Vietnamese). http://old.tnu.edu.vn/QLKH_Documents/DH2013.TN02.06-BCTT.pdf
3. **H.Z. Choi, S.W. Lee, H.D Jeong** (2001) *A comparison of the cooling effects of compressed cold air and coolant for cylindrical grinding with a CBN wheel*, *Journal of Materials Processing Technology* 111:265-268.
4. **K.Q. Xiao, L.C. Zhang** (2006) *The effect of compressed cold air and vegetable oil on the subsurface residual stress of ground tool steel*, *Journal of Materials Processing Technology* 178:9-13
5. **Sudheesh, P. K., & Govindan, P.** (2013). *Experimental investigations and optimization of jig grinding process*. *International Journal of Research in Engineering & Technology*, 1(3), 65-76.
6. **S. Krishnakumar, P. Vijayakumar & R. Makeshkuma**(2017) *Evaluation of Machinability of D2 Steel using Cryo Treated Cermet using Taguchi Technique*, *International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)*, Vol. 7(3), 7-16
7. **Hoang Xuan Tu, Vu Ngoc Pi, Gong Jun** (2019) *A Study on Determination of Optimum Parameters for Lubrication in External Cylindrical Grinding Base on Taguchi Method*, *Key Engineering Materials*, Vol. 796:97-102
8. **Hoang Xuan Tu, Gong Jun, Bui Thanh Hien, Le Xuan Hung, Luu Anh Tung, Vu Ngoc Pi** (2018) *Determining Optimum Parameters of Cutting Fluid in External Grinding of 9CrSi Steel using Taguchi Technique*, *International Journal of Mechanical Engineering (SSRG - IJME)*, Volume 5 Issue 6: 1-5
9. **M. Kiyak, O. Cakir, E. Altan** (2003) *A Study on Surface Roughness in External Cylindrical Grinding*, 12th International scientific conference – Achievements in mechanical & materials engineering (AAME):459-462
10. **Choi H. Z, Lee S. W, Kim D. J** (2001) *Optimization of Cooling Effect in the Grinding with Mist Type Coolant*, Korea Institute of Industrial Technology. http://www.aspe.net/publications/annual_2001/pdf/posters/process/grind/1234.pdf
11. **Do Duc Trung** (2010) *Research on the influence of lubricant on surface quality when grinding SUJ bearing steel with Al_2O_3 and CBN grinding wheel on surface grinder*, Master thesis, Thai Nguyen University of Technology (Vietnamese). <https://text.123doc.org>
12. **Ngo Cuong, Nguyen Dinh Man** (2009) *Research on choosing cutting parameters and technological measures for improvement of economic and technical efficiency when grinding 3X13 stainless steel with Hai Duong grinding wheel*, Science research project at ministerial level, Thai Nguyen University (Vietnamese) <https://text.123doc.org>

13. **Nabil Ben Fredj, Habib Sidhom, Chedly Braham** (2006) Ground surface improvement of the austenitic stainless steel AISI304 using cryogenic cooling, *Surface & Coatings Technology*, 200:4846-4860
14. **Nguyen Thi Thu** (2015) Research on the influence of cooling-lubrication technology on the machined surface quality when grinding 9XC tempered steel through with Hai Duong grindstone, Master thesis, Thai Nguyen University of Technology (Vietnamese).

<https://text.xemtailieu.com>
15. **Webster J.A, Cui C** (1995) Flow rate and jet velocity determination for design of a grinding cooling system, *Technical Papers Supplement of the First International Machining and Grinding Conference, Dearborn, Michigan, 12–14/9/1995*, pp. 345-356.
16. **Stephenson. D J, Jin. T** (2003) Physical basics in Grinding, *European Conference on Grinding, Aachen*, pp. 13-21.
17. **Raymond H. Myers, Douglas C. Montgomery, and Christine M. Anderson-Cook** (2009) *Response Surface Methodology: Process and Product Optimization Using Designed Experiments*, John Wiley & Sons, Inc., 3rd Edition.